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Improving Water Quality and Sanitation Through Growth and Aid: The Case of Africa

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Abstract

Poor water quality in the region is also a result of untreated waste water, such as industrial and domestic waste, entering water sources. The combination of dangerous waste and naturally existing chemicals in the bed rock allow for disease and contamination to spread. Water, therefore, has an extremely high level of toxic pollutants such as heavy metals, persistent organic pollutants, and biological contaminants. It is difficult for African countries to implement water management programs because many African governments do not establish water quality monitoring programs. Data on water pollution in present day is also as a result very limited, as are analytic laboratories where water quality can be studied. Without a structured framework for water governance, it has become apparent that African governments are finding it hard to manage their own water sources efficiently.

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I. INTRODUCTION

It's not the amount of water that matters, it's the quality of the water consumed that is most important. For an agricultural continent, like Africa, that relies so heavily on physical labor, improvements in water quality could improve health for those employed on farms. 90 percent of human health depends on consumed water, making the availability of safe drinking water a top priority in African nations.

UNICEF's seventh Millennium Development Goal is to reduce the portion of people without access to safe drinking water and basic sanitation in half by 2015. Failure to obtain safe water leads to widespread diseases like cholera and infant diarrhea. The poor health of an economy can be attributed to unclean water and lack of proper sanitation facilities, which in turn can hinder the learning potential of children and the further development of the country as a whole.

Lakes, rivers, and ground water are all sources from which people can obtain drinking water. Water from each source will need to go through some purification processes to attain the acceptable level before it can be consumed. Whether or not water can be used for drinking after being treated heavily depends on the raw water source quality. For example, surface water collects hazardous runoff as it flows through rivers, which needs more purification, while most ground water is mildly contaminated and requires less treatment. There are two methods of treatment: point of entry treatment and point of use treatment. Disinfecting is a point of use treatment, but it does not ensure that drinking water is safe. The chemicals used during point of use treatment to disinfect pathogens are a health hazard in high quantities.

Only 62 percent of Africans have access to safe water. 75 percent of drinking water comes from groundwater and is consumed with little or no purification. And when drinking water is not easily accessible on land, women bear the burden of collecting it. In research done by the World Health Organization (WHO) and UNICEF, it found that women in African are more than five times as likely as men to walk to a source in order to collect drinking water for the entire household.

In Africa, poor legislation on water pollution and regulation of water activities leave much of the raw water sources untreated and unprotected. Dirty, contaminated water leads to an ongoing cycle of poor health, which in turn impacts more aspects of life such as the level of education attainment existing poverty. Since 85 percent of water resources in African are shared river basins there is unequal usage of the water among citizens. This is due to the varying social, political, and economics structures adopted by individual countries. The different priorities of each country result in large fluctuations in usage and high demand for water.

Safe drinking water is scarce in Africa primarily due to practices of open defecation and poor sanitation facilities. Fecal pollution is among the most pressing concerns on the continent with regards to safe drinking water. In addition, fecal pollution is the largest contributor of water born diseases such as typhoid.

Poor water quality in the region is also a result of untreated waste water, such as industrial and domestic waste, entering water sources. The combination of dangerous waste and naturally existing chemicals in the bed rock allow for disease and contamination to spread. Water, therefore, has an extremely high level of toxic pollutants such as heavy metals, persistent organic pollutants, and biological contaminants. It is difficult for African countries to implement water management programs because many African governments do not

establish water quality monitoring programs. Data on water pollution in present day is also as a result very limited, as are analytic laboratories where water quality can be studied. Without a structured framework for water governance, it has become apparent that African governments are finding it hard to manage their own water sources efficiently.

II. LITERATURE REVIEW

There are several paths that can lead towards improved water quality and sanitation facilities. Working with governments to improve technology and hygiene education decreases the inefficiencies in wasted freshwaters and the need for treatment. Developing low cost programs that address efficient use and promote hygiene should be the primary focus of African countries. The African Development Bank Group founded in 1964 works on several developmental efforts throughout the continent including water and sanitation (OWAS). The OWAS department reported on the water and sanitation index of development effectiveness in Sub-Saharan Africa in February of 2012. The study compares the countries' performance in the water and sanitation sectors and analyzes how well the outputs correlate with the resources and developmental aid that they receive (Stampini, et. al., 2012). This is compiled in the Watsan Index of Development Effectiveness (WIDE). Gabon and Mauritius were found to be better off in terms of resources than the other Sub-Saharan countries, in that they received over 10 USD per capita per year of Official Development Aid (ODA) to assist their water and sanitation sectors (Stampini, et. al., 2012). Gabon, in addition, also has more water resources per capita, about 58 times more than Mauritius. Mauritius, while lacking in water resources, has the least amount of corruption and the best governing body to allow for progress and efficient use of resources (Stampini, et. al., 2012). Relative to Gabon and Mauritius, Zimbabwe and the Democratic Republic of Congo have the least amount of ODA per capita and water resources in addition to having a highly unstable government structure that is more conducive to corruption and less likely to successfully implement new initiatives. This study helps clarify the positive relationship between GDP and ODA on water quality and sanitation; however it does not address the impacts of education or human capital's impact on water quality.

With respect to the quality of life, research has found that there are non-economic factors that impact the quality of life, in addition to the conventionally measured economic factors of income, growth, poverty, and inequality (Lee, et.al., 1982). Non-economic measures such as happiness, satisfaction, and optimism react slowly and are more costly to measure than the conventional economic factors. In addition, growth in economic factors, such as an increase in per capita income, does not necessarily correspond with increases in the general well being of human life (Rossouw, 2008). Despite the difficulty of measuring these variables, the quality of life measurements can prove useful for policy makers. Nleya (2008) claims that there is a direct relationship between the standard of water services and the poverty level. Kapatamoyo (2004) similarly states that the mere lack of clean water is a manifestation of poverty, which has serious consequences for the survival of individuals and communities.

As of 1990, the United Nations Development Program created the Human Development Index that averages values for income, life expectancy, and literacy into a single measure (Rossow, 2007). The purpose of the measure is to shift policy focus away from national income accounting to people centered policies. This shift is done in order to evaluate human development by not only economic advances, but also through improvements in overall human well-being. But critics of the HDI say that life expectancy and literacy are too closely correlated with Gross National Product (GNP) per capita, which makes the index redundant. Rossouw and Naude (2007) developed their own measures and found that in South Africa the most populous cities were not the cities with the best geographical and environmental quality of life. The areas with the highest quality of life were those that were sparsely populated with lower than average per capita income. While their research looks at the relationship between non-economic factors and quality of life, there is little research on the impacts of water accessibility or water cleanliness on quality of life.

The benefits of higher quality water and sanitation suggest lower healthcare costs and an increase in productivity of workers (Hutton et al., 2007). On the cost side, the water supply and sanitation industry is a natural monopoly because the fixed costs for entering the industry are so high. Due to the class nature of water problems, there is no real incentive for elites to invest in this industry if they already have water security, which is the idea that water is accessible and affordable to allow people to lead a healthy, dignified, and productive life and that ecological systems are maintained in a sustainable level (Nleya, 2008). By encouraging investment in this monopolistic market, Nleya (2008) states it is important

to produce at the socially optimal level instead of at the profit maximization level, which will allow for water security to increase for more individuals and ultimately positively impacting their quality of life.

III. THEORETICAL FRAMEWORK

Grossmand and Krueger (1995) along with the World Bank found that pollution in developing economies first increases and then decreases as the country's wealth increases over time. They captured this theory in the environmental Kuznets curve (henceforth EKC). This is similar to Simon Kuzenets' idea of income inequality. It can be seen from the figure that, income inequality and pollution is greatest for middle-income countries. Grossmand and Krueger (1995) support their findings from air and water quality experiments, which is why their conclusions can hold true for water and sanitation. These conclusions seem reasonable as most developing countries do not have the technology or resources with which to produce sustainably. Thus, as a country becomes more financially stable and wealthy, it can be expected that the country will have more resources to dedicate towards improving production processes that reduce pollution.

The EKC can be divided up into three parts: scale, composition, and technique. In theory, as an economy grows the scale of all activities increases proportionally. This implies that pollution will grow proportionally to the economy's growth. However, the growth of an economy can change if the composition of the goods produced change. For example, if richer countries produce less polluting goods, due to a change in preferences, then the composition effect leads to a decline in overall pollution as economic growth continues. In addition, pollution also falls if richer countries adopt new technological practices that reduce pollution residuals.

Greater economic activity hurts the environment initially due to the lack of technology and environmental investments available for low-income countries. However, as income rises, the demand for improvements in environmental quality increases; resources available for investment will also increase. Beckerman (1992) claims that "there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best-and probably the only-way to attain a decent environment in most countries is to become rich." Therefore, countries should strive to increase their overall national income, in hopes of reducing pollution in the future.

According to the United Nations, many African nations are in the pre-industrial economy stage and are classified by the United Nations as least developed countries (LDCs). Thirty-four African countries fit the criteria of an LDC (See Appendix A for a complete list). Criteria for inclusion in this category include (a) a gross national income per capita of 750 dollars or less, (b) a weak human assets index that reflects nutrition, health, education, and adult literacy, and (c) economic vulnerability as measured by instability in agricultural production and instability in exports.

Using the EKC framework of Grossmand and Krueger (1995), it is therefore hypothesized that GDP, HDI, and ODA (defined in Appendix B) will have a positive impact on water quality and sanitation.

IV. EMPIRICAL RESEARCH, DESIGN, & DATA

A simple OLS regression of paneled data is conducted. The four regressions, shown below, predict improved water sources and improved sanitation facilities respectively, definitions for all variables can be found in the Appendix. The first two regressions predict the dependent variables separately through HDI and ODA, and the second set of regressions includes ODA and GDP. GDP and HDI are collinear variables that generally move in the same direction, so to isolate their effects separate regressions were performed. HDI includes a Gross National Income (GNI) component that is similar to GDP, therefore by performing separate regressions eliminates the redundancy or double counting for GDP. The regressions run in SPSS as follows:

y1=Improved Water Source

$$y1=\beta0 + \beta1(LN_{ODA}) + \beta2(LN_{ODA}) + \beta3(1990) + \beta4(1995) + \beta5(2000) + \beta6(2005) + \beta7(2006) + \beta8(2007) + \beta9(2008) + \beta10(2009) + \beta11(2010)$$

y2=Improved Water Source

$$y2=\beta0 + \beta1(HD1) + \beta2(LN_{ODA}) + \beta4(1995) + \beta5(2000) + \beta6(2005) + \beta7(2006) + \beta8(2007) + \beta9(2008) + \beta10(2009) + \beta11(2010)$$

y3=Improved Sanitation Facilities

$$y3=\beta0 + \beta1(HD1) + \beta2(LN_{ODA}) + \beta4(1995) + \beta5(2000) + \beta6(2005) + \beta7(2006) + \beta8(2007) + \beta9(2008) + \beta10(2009) + \beta11(2010)$$

y4=Improved Sanitation Facilities

$$y4 = \beta 0 + \beta 1(HDI) + \beta 2(LN_{ODA}) + \beta 4(1995) + \beta 5(2000) + \beta 6(2005) + \beta 7(2006) + \beta 8(2007) + \beta 9(2008) + \beta 10(2009) + \beta 11(2010)$$

The data for this study is derived from the World Bank Dataset, which is an important source of financial and technical assistance to developing countries. Drawn from this data base were the following variables: Human Development Index, GDP per capita, Improved Sanitation Facilities, Improved Water Source, and Net Official Development Assistance received. See Appendix B for World Bank definitions of the variables as well as how they are calculated.

The time period for the data begins in 1990. Prior to 1990 few African countries reported per capita GDP and any other variable used. The years that include complete data are 1990, 1995, 2000, 2005, 2006, 2007, 2008, 2009 and 2010. The gaps in years can be attributed to the political turmoil of African countries, such as civil wars, which make gathering and sharing data costly and difficult. All African countries were included with the exception of Sao Tome and Principe, Seychelles, Somalia, and South Sudan due to the fact that little data is available for the above mentioned variables. See Appendix C for a full list of countries included in this study.

GDP and ODA were adjusted for by taking the natural log of each variable, so that the results were not dominated by one variable having large absolute values. This is an important step since HDI, IWS and ISF are in absolute terms which are relatively smaller than GDP and ODA. Ideally, literacy, life expectancy, employment, democratic freedom, government corruption levels and pollution variables would have been included, but data for those variables are not reported for the years used in this study. Instead the Human Development Index is used, which includes its own measures for literacy and life expectancy.

A control for time is also included. The data was compiled in a panel comprising of 50 countries over nine observed years. The regression spans a total of 450 observations. Cases in specific years where GDP, HDI or ODA were not reported were omitted from the regression.

V. RESULTS

This first regression, which is reported in Table 1, shows that both HDI and ODA have a significant impact on the accessibility of water. HDI increases accessibility to water by 84 points. On the other hand, a one percent change in ODA reduces accessibility by 3 percent. The sign for HDI is positive and thus consistent with the hypothesis. However, ODA is negative and thus does not support the original hypothesis that ODA would have a positive impact upon water quality. T-statistics for both values are greater than 2 or -2, which indicate that the coefficients are significant with a greater than 95 percent confidence level. The R Square is 46.2 percent, which explains the total variation by HDI and ODA for the improved water source. The results indicate that there is a significant positive correlation between HDI and water quality, the greater the HDI is the greater the percentage of people with access to an improved water source.

In the regression shown in Table 2, the second regression, HDI has a greater impact on access to proper sanitation facilities than it did on accessibility to water. ODA has a negative impact but it is not significant at the 0.1 or 0.05 level, meaning the variable is unable to conclude its impact on sanitation. The t-statistic for HDI is greater than 2, indicating that the coefficient for the variable is significant above a 95 percent confidence level. The same cannot be said for ODA, since the t-statistic is less than -1.68, which is not significant with 90 percent confidence level or greater. The hypothesis for HDI is supported in that it has a positive impact on sanitation, however the hypothesis does not hold true for ODA since it is not significant enough. 48.2 percent of the total variation in improved sanitation facilities variable is explained by HDI and ODA. The results indicate that there is a significant positive correlation between HDI and sanitation. The greater the HDI is, the greater the percentage of people with access to improved sanitation facilities.

In Table 3, for regression 3, we predict accessibility to water but with the use of GDP instead of HDI. The regression shows that both GDP and ODA have a significant impact on accessibility of water. A one percent change in GDP causes a 9.8 percent increase in accessibility to water, while a one percent change in ODA causes a 2 percent decrease in accessibility. The t-statistics for both variables are greater than 2 or -2, implying that the coefficients for those variables are significant with a greater than 95 percent confidence level. In addition both are significant at the p-value of 0.05. 44.1 percent of the variability in the improved water source is explained by GDP and ODA. Despite

this, the hypothesis again does not hold true for ODA, but it does support the positive impact which was expected for GDP to have. Thus there is a strong positive correlation between GDP and improved water sources, so as GDP increases the percentage of people with access to quality water also increases. There is a negative correlation between ODA and an improved water source so as ODA increases the percentage of people with access to water decreases.

Table 4 predicts accessibility to an improved sanitation facility by using GDP and ODA in regression 4. The regression results show that GDP has a significant impact on access to better sanitation. A one percent change in GDP causes a 17.5 percent increase in accessibility to proper sanitation, while a one percent change in ODA causes a 0.678 percent increase in accessibility. However since the coefficient for ODA is not significant at the 0.1 or 0.05 levels we cannot conclude its impact on sanitation. The t-statistic for GDP is greater than 2, indicating that the coefficient is significant at significance level greater than 95 percent; my hypothesis holds true for GDP. However the same cannot be said for ODA. The t-statistic for ODA is less than 1.68 thus it is not significant at 90 percent confident level or greater. The results do not support the hypothesis because they do not show a significant positive correlation to improved sanitation facilities. 50.9 percent of the variability in improved water sanitation can be explained by GDP and ODA. Thus as GDP increases we can expect the percentage of people with access to sanitation to also increase.

VI. CONCLUSIONS & POLICY IMPLICATIONS

In conducting research on water quality and sanitation, it is expected to find that an increase in GDP, HDI and ODA would all correspond with an increase in water quality and sanitation. According to the theory underlying the EKC, the richer a country becomes the less polluted its environment should be. Less pollution implies fewer people pollute and water quality increases.

This study found that GDP had a significant positive impact on water quality and sanitation, meaning that as the GDP per capita in African countries increases it can be expected that the accessibility to quality water and proper sanitation increase. This implies that countries should continue to do what they have been doing in order to increase their GDP per capita. HDI also had a significant positive correlation to water and sanitation, implying that the components of HDI should also continue to improve. If a person lives a longer lifespan, they become more educated, and make a greater income. With a larger income, the people of African are more likely to invest and promote accessibility to water sources and improved sanitation facilities.

Taking this research further, there is a dire need for data collection on the African continent. Specifically, a database needs to be developed over time so that it includes more direct variables that could predict quality water. These variables should include: the distance and time it takes to collect water on a regular basis, pollution levels of nearest water source, amount of surface and ground water available in the country, and lastly an index that measures the stability of the government. An increase in the amount of surface or ground water available would mean that, that country should most likely receive more aid in developing better water management systems because they have the natural resources available to work with. In addition if an index were developed to measure the stability of the government over time, the more stable the government, the less likely it is that corruption will take place. If there's less corruption, then the success rate of a water and sanitation management program is a lot higher, and thus the likelihood of improving water quality and sanitation increases.

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VIII. APPENDIX

Table 1: Regression Results: Dependent Variable is Improved Water Source		
Variable	Coefficient	T-Statistic
HDI	84.63*	15.004
LN_ODA	-2.889*	-4.949
Adj R Squared	.462	
Sample Size	390	
* Denotes significanct at the .05 level		

Table 2: Regression Results: Dependent Variable is Improved Sanitation Facilities		
Variable	Coefficient	T-Statistic
HDI	138.635*	17.729
LN_ODA	-.973	-1.192
Adj R Squared	.482	
Sample Size	394	
*Denotes significant at the .05 level		

Table 3: Regression Results: Dependent Variable is Improved Water Source		
Variable	Coefficient	T-Statistic
LN_GDP	9.841*	14.312
LN_ODA	-2.377*	-3.898
Adj R Squared	.441	
Sample Size	424	
*Denotes significant at the .05 level		

Table 4: Regression Results: Dependent Variable is Improved Sanitation Facilities		
Variable	Coefficient	T-Statistic
LN_GDP	17.504*	19.672
LN_ODA	.678	.849
Adj R Squared	.509	
Sample Size	426	
*Denotes significant at the .05 level		

Appendix A: List of Least Developed Countries in Africa			
Angola	Djibouti	Liberia	Sierra
Benin	Equatorial Guinea	Madagascar	Sao Tome and Principe
Burkina Faso	Eritrea	Malawi	Sudan
Burundi	Ethiopia	Mali	Somalia
Cape Verde	Gambia	Mauritania	Tanzania
Central African Republic	Ghana	Mozambique	Togo
Chad	Guinea	Niger	
Comoros	Guinea-Bissau	Rwanda	Uganda
Conog, Dem. Rep.	Lesotho	Senegal	Zambia
Source: United Nations			

Appendix B: Definitions of ariables used and how they are mesaured
Human Development Index
The Human Development Index (HDI) is a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development: a long and healthy life (health), access to knowledge (education) and a decent standard of living (income). The HDI was created to emphasize that people and their capabilities should be the ultimate criteria for assessing the development of a country, not economic growth alone. The HDI can also be used to question national policy choices, asking how two countries with the same level of GNI per capita can end up with such different human development outcomes.
GDP per capita (constant 2000 US$)
GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant U.S. dollars.
Improved Water Source (% of population with access)
Access to an improved water source refers to the percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection. Unimproved sources include vendors, tanker trucks, and unprotected wells and springs. Reasonable access is defined as the availability of at least 20 liters a person a day from a source within one kilometer of the dwelling.
Improved Sanitation Facilities (% of population with access)
Access to improved sanitation facilities refers to the percentage of the population with at least adequate access to excreta disposal facilities that can effectively prevent human, animal, and insect contact with excreta. Improved facilities range from simple but protected pit latrines to flush toilets with a sewerage connection. To be effective, facilities must be correctly constructed and properly maintained.
Net Official Developmental Assistance

Net official development assistance (ODA) consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries to promote economic development and welfare in countries and territories in the DAC list of ODA recipients. It includes loans with a grant element of at least 25 percent (calculated at a rate) of discount of 10 percent). Data are in constant 2009 U.S. dollars.

Appendix C: African countries included in empirical study

Algeria	Cote d'Ivoire	Liberia	Rwanda
Angola	Djibouti	Libya	Senegal
Benin	Egypt, Arab Rep.	Madagascar	Sierra Leone
Botswana	Equatorial Guinea	Malawi	South Africa
Burkina Faso	Eritrea	Mali	Sudan
Burundi	Ethiopia	Mauritania	Swaziland
Cameroon	Gabon	Mauritius	Tanzania
Cape Verde	Gambia, The	Morocco	Togo
Central African Republic	Ghana	Mozambique	Tunisia
Chad	Guinea	Nambia	Uganda
Comoros	Guinea-Bissau	Niger	Zambia
Congo, Dem. Rep.	Kenya	Nigeria	Zimbabwe
Congo, Rep.	Lesotho		

Note: Sao Tome and Principe, Seychelles, Somalia, and South Sudan were excluded from study due to data inaccessibility.